The use of simulators in basic driver training

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Abstract

What is discussed in this paper is how driver simulators can best be used for basic driver training. The emphasis is not on the technical requirements but on the didactical requirements and the development of so-called courseware. A comparison is made between the use of simulators for training pilots and the use of simulators for drivers. How successful can learner drivers be trained with the aid of a simulator and what kind of skills can best be trained with the aid of a simulator? Examples are given of (1) a basic driver training programme where the only training device is a simulator (no training on the road), (2) a training programme where simulator training and multi media training are integrated in the training programme, and (3) the use of a driver simulator for the acquisition of higher order skills. It seems that driver simulators can accelerate the process of the acquisition of basic driving skills, but there are doubts about the retention of these skills. If driver simulators can be used for the training of higher order skills like risk perception and situational awareness, is not clear yet.

Introduction

Ever since the development of the first driving simulator, driving simulators have been considered as powerful training devices. In this paper, aspects will be highlighted that deal with how to train with the aid of driving simulators and the role driving simulators can have in a curriculum for basic driver training. The technical qualities of driving simulators will not be discussed. Subjects that will be discussed are (1) Why is the effectiveness of driver simulators for training purposes rated so high? (2) Is it possible to learn to drive a car solely on a driver simulator? (3) How effective can a driver simulator be in comparison to a flight simulator? (4) Can higher order skills effectively be trained on a driver simulator?, and (5) Can a driver simulator form an integrated part of a basic driver training programme?

Why are driver simulators seen as potentially very effective training devices?

Compared to driving lessons in a car on the road, driving simulators have several advantages. The advantages are:

- *Control over the training conditions*. If for instance, a learner driver has difficulties to merge onto a heavily used motorway, in reality the driving instructor has to wait for the proper conditions, and the task can only be rehearsed after having left the motorway at the next exit. In a driving simulator, the instructor can set the proper conditions. The task can immediately be repeated and be rehearsed as often as wanted until the skill is acquired;
- *Safe training conditions*. In a driving simulator it is possible to train aspects of the driving task that in reality would be too dangerous for the learner driver;
- *Improved feedback and instruction possibilities*. In reality, a driver instructor tells a leaner driver what to do and comments on what the learner driver has done well and what he/she has done wrong. In a driving simulator the performance of the learner driver can be accurately measured and be automatically registered (speed, headway, reaction time, etc.). As soon as the learner driver exceeds certain thresholds, timely and automatic feedback can be provided. This feedback does not have to be verbal. It can also be visible information on the screen. In simulator conditions

it is also quite easy to register the driver behaviour on video, and replay the video in the debriefing just after the training session.

From the beginning, one disadvantage has also been recognized. A simulator is always an imitation of reality and that imitation is never perfect. It is questioned if there will be *transfer* of what is learned in a simulator to the real world if the imitation of reality in the simulator is poor. The idea that it is necessary to copy reality as wel as possible has put a lot of emphasis on the technical validity of driving simulators for training purposes. This has made driving simulators too expensive to be used for basic driver training. Because of rapid developments in computer technology (more powerful PCs, better graphic cards, beamers) parts of the driving simulator could improve enormously and could also be produced much cheaper. This made low cost simulators (with a very limited field of view and no moving base) and the Mean Cost driving simulator (with a wider field of view, some mechanical feedback but still no moving base) recently attractive for commercial driver training.

Now driving simulators have come available for training purposes on a large scale, the question is not so much how well they copy reality, but how they can best be used. As such, a driving simulator has no meaning. It is the way it is used to acquire skills and the way it is used in combination with other training methods and training devices, both traditional (driving instruction on the road, accompanied driving, textbooks) and new (computer aided instruction), that is decisive for effectiveness and efficiency of the driving simulator. For training purposes, a very realistic imitation of reality can even hamper skill acquisition. When acquiring complex skills, in the beginning, a reduced representation of reality is preferred over a detailed representation. A reduced representation will help the learner driver to focus on the core of the skill. Deviations from reality can also be helpful. With simulators it is plausible to provide feedback by means of projection of visual aids on the screen. These visual cues do not exist in reality but help the driver to acquire skills.

Learning to drive solely on a simulator

In the Netherlands in the mid 1990s, a small but interesting experiment took place (Wierda, 1996). Six subjects (three men and three women) who had never driven before and never had one single driving lesson, followed a training course on a driving simulator. This training course was the so-called Personalized Adaptive Cybernetic Training system (PACT) and was developed at the former Centre for Environmental and Traffic Psychology (COV) of Groningen University. The PACT training method was derived from cognitive-psychology theory on how to acquire perception strategies and how to learn to act in time and space. The whole curriculum consisted of 13 modules. Each training module had its own set of training objectives and one could only start with the next module after having finished the previous one. A strict distinction was made between vehicle manoeuvring skills, the mastery of traffic situations and calibration. Calibration is the ability to adapt the driving task to one's capabilities. Driving is to a large degree self paced. If someone drives faster, the task demands will increase. Calibration is to know one's limitations and it requires meta-cognition.

During the training sessions, route-instructions (turn left at the next junction, etc.) were not provided orally by the instructor but appeared visually on the screen. This was done to avoid interference of route-instruction with the driving task as much as possible. The 'environment' (road type, traffic lights, intersections, roundabouts etc., and the traffic intensity) in which the learner driver had to drive in the simulator differed from module to module and gradually grew in complexity over the modules. Most of the other vehicles drove according to pre-programmed computer instructions but the operator/ instructor could manipulate 'target' cars if the curriculum so required. An example is that the operator/instructor could let another car overtake the simulator car in circumstances that the learner driver had to brake in order to avoid a crash. Feedback was provided in various ways. There was verbal 'on-line' feedback from the instructor/operator. In the debriefing after the module, the parts where the behaviour was inadequate were 'replayed' from different angles and, if necessary, in slow motion.

In all simulator sessions, skill improvement with regard to vehicle manoeuvring and the mastery of traffic situations was constantly recorded. It appeared that improvement in almost all skills developed in accordance with the power function of practice. (Newell & Rosenboom, 1981). This means that the gain from practice is considerably greater early in learning than it is later in learning. The formula for power functions of practice is:

$$\text{Number of Errors} = \text{Initial Level} \times \text{Amount of Practice}^{-\text{Rate of Learning}}$$

In other words, if it takes 100 trials to half the initial amount of errors, according to the power function of practice, it takes N times N-1 trials (= 9900 trials) to half the number of errors again.

After having completed the PACT simulator training programme, which meant 6 times 1½ hours (= 9 hours) simulator training, the performance of the subjects during a simulator drive was rated by a professional driving examiner. He rated one subject as ready for the official driving test, four as almost ready and one about half way. After this, the subjects started to drive in a real car (with a driving instructor next to them) for the first time in their lives. At first, all subjects experienced difficulties in manoeuvring a real car. Apparently, transfer of vehicle handling from a simulator without a moving base to a real car, was quite poor. However after the simulator training, the subjects managed to learn very rapidly to manoeuvre a real car. After only a short training, especially in braking (about half an hour's training), they could handle a real car quite properly. Immediately after this short training five subjects did the driving test in the real traffic environment. This was not the official Dutch driving test, but a test that was very similar. The examiner was an experienced driving instructor. If it have been the official Dutch driving test then two would have passed the test, two were just below the required level, and one was clearly not good enough.

This experiment indicates that at least some people can learn to drive on a rather good simulator, and a well-designed simulator-training programme very rapidly (without any prior driving experience being able to pass the driving licence test after just 9 hours simulator training). However, this experiment says nothing about the safety performance of these simulator-trained drivers in real traffic. What would be interesting to know is what the crash rate of drivers solely trained on a simulator is in the first period after having passed the driving test compared to traditionally trained driver in the same period. What might be questionable is the retention of the skills that have been acquired in such a short time.

Learning to fly and learning to drive

Driving is a complex task and for a novice driver it requires years of driving experience for the crash rate to reach its lowest level. Apparently a lot of varied practice is required to become a safe driver. Can driver simulators shorten this process? In aviation, simulators seem to shorten the learning period. Flying is also a complex task and flying simulators are widely used for training purposes. Without doubt, flying would not be as safe as it is now without the use of simulators. Why then can a flying simulator be considered as a kind of pressure cooker for learning to fly, and a driving simulator probably less so for learning to drive safely? Wheeler & Trigs (1996) have compared the flying task with the driving task. They have looked at *procedural tasks* (if this is the case first do this and then do that), *tracking task* (keeping speed and course (in cars) and altitude also (in planes), *task in emergency situations* (what to do when an engine breaks down in a plane or how to get a car out of a spin), and the so called *higher order tasks* (situational awareness, risk perception).
According to Wheeler & Trigs, flying simulators have proved to be good training devices for all four different kinds of task. With regard to the *procedural tasks,* flying is much more often carried out at the rule based level than driving is. To a large extent, flying is checking displays, and if a certain threshold is reached, then first do this and then do that. A pilot has become a kind of supervisor of various processes and he only has to act if the mainly automated processes do not run according to plan. In contrast, a driver is much more an operator (has to act himself) in an environment that is less predictable. In principle, it is possible to fly an airplane without a window in the cockpit but it is not possible to drive a car without windows. Procedural tasks can be trained in a simulator very effectively. This is also true for driving, but because the driving task is to a lesser extend procedural, the benefits are not as great.
For learning to manoeuvre a car and to 'manoeuvre' a plane, simulators can be used, but only to a certain extend. Even if the simulator has a moving base, feedback of forces is never perfect. The urge to learn to manoeuvre a car in a simulator is not so high. Lack of motor control skills is rarely the cause of crashes in which young novice drivers are involved. One can probably learn to manoeuvre a car in safe traffic conditions much cheaper and better in a real car than in a simulator. As flying is more expensive than driving, learning to 'manoeuvre' a plane in a simulator is cost effective, whereas it is not for learning to manoeuvre a car.
The flying simulator is the ideal training device for emergency situations. It is not possible to train these situations in reality without risking lives. In flying, to a large extent, the training of emergency situations is the training of procedures. On the road, emergency situations are different. They do not require so much the use of proper procedures on the rule based level, but the use of (very often counter intuitive) skills on the automated level. How to react automatically in a split second when your

car starts to spin? For skid training, a very advanced driver simulator with a moving base is required. Besides this, skid training has appeared to be counterproductive. Drivers that have attended a skid training wrongfully consider themselves as better drivers than they actually are. As a result of this they take more risks and more often get involved in crashes. What should be trained is not what to do when your car is spinning but to avoid situations in which your car might start to spin. This is a higher order ability.
Wheeler & Trigs think that out of the four different tasks, driver simulators can be very useful for the training of higher order skills. Higher order tasks are not usually associated with closed system dynamics (as procedural tasks are) but with the external environment. Higher order tasks are performed at the knowledge based level and require that all steps in perceptional cognitive process (perception, diagnoses, prognosis, decision and action) are made consciously and deliberately. They think that simulator training might enhance the acquisition of higher order skills, but they do not say why.

The theoretical work of Groeger (2000) and Christie & Harrison (2003) casts some doubts on the usefulness of driver simulators for the acquisition of higher order skills. According to Groeger simulators make it possible to structure driver training much more, and make it also possible to introduce mass repetition of skills. From laboratory experiments it is known that splitting up tasks into part tasks and mass repetition of part tasks, helps to speed up the learning process; but retention is worse. This is in particular the case when subjects themselves have to conclude from the context what skills have to be applied. Because of this, Groeger thinks that associative learning during many hours behind the wheel (with an experienced driver next to the learner driver) in varied conditions, is better for the acquisition of higher order skills than structured simulator training in a reduced environment. Associative learning in real life takes more time, but retention is much better. Along more or less the same lines, Christie & Harrison argue that situation awareness is the product of experience rather than education. To speed up the learning process, the context can be arranged (first driving on simple roads with no traffic, and gradually building op the complexity of the context) but it is not useful to split up the tasks and train them separately.

Training of higher order skills with the aid of a simulator

In the paragraph above, from a theoretical point of view, some doubts were raised about the usefulness of driver simulators for training purposes. Even the use of driver simulators for the acquisition of higher order skills was questioned. Only experiments can prove if these doubts have any validity or not. One of the aims of the EU-TRAINER project was to develop guidelines for the use of simulators in driver training. In Sweden these guidelines were used to develop a training module for the improvement of hazard perception skills. Both computer aided instruction and simulator trainings were developed. Falkmer & Gregersen (2003) have tested how successful the hazard perception training with multi media training on a PC and simulator training was. As training simulators, a so-called Low Cost Simulator (LCS) and a so-called Mean Cost Simulator (MCS) were used. A LCS consists of a driver chair, pedals, a gear lever, a steering wheel, a dashboard, only one monitor (40 degrees field of view) right in front of the driver, and a sound generator. It has no moving base but pedals and a steering wheel counterpoise. A MCS has the same configuration but with 3 monitors (a field of view of about 120 degrees). All the subjects were learner drivers from a driving school. They had professional driver training (on the road) but had not done the driving test yet. The subjects were divided into three groups. The first group first did the multi media training on a PC, and after that received the simulator training on a MCS. The second group also first did the multi media training on a PC, but received the simulator training on a LCS. The third group (the control group) neither did the multi media training nor received simulator training. To test the acquired training skills, the full mission VTI research simulator with a moving base was used. In this simulator six scenarios were offered. In the first scenario the subject drove in an urban environment. At a junction, a bus approaches from a right hand side road. According to the rules of the road, the bus should have stopped but it did not. This situation demands early detection and immediate reaction in order to avoid a collision. In the second scenario the subject drove on a rural road with forest all around. A moose suddenly crossed the road and, after some seconds, two calves followed. In this condition situation awareness is required for early detection. The third scenario, when driving on a rural road, the subjects receives an SMS on their mobile phone. Directly after the phone signal, the subject passed a traffic sign with a lower speed limit (it was 90 km/h and the sign was 50 km/h). Is the subject distracted by the phone signal or does he/she recognize the change in speed limit in time (by reducing speed)? Scenario four is one long scenario divided into three parts. In the first part, fog gradually reduces the visibility to 100 metres. Does the subject notice gradual decrease in visibility in time and does he/she adjusts his/her

speed? The fog disappeared and then the driver entered a second fog bank. In that fog bank a van appeared that is driving in the same direction. If the subject is driving too fast, a rear-end collision will occur. And finally, while driving behind the van, the fog disappears, but then the van starts to accelerate. Will the subject also start to accelerate (over the speed limit) or not?

There were no significant differences between the three groups with regard to the bus-, moose- and car following scenarios. With regard to the SMS scenario the subjects that were trained in the MCS did significantly better than the control group (group 3) and the group that was trained in the LCS. With regard to the two fog scenarios, the MCS trained group performed significantly better than the control group with regard to timely speed adjustment. Keeping distance to the van in the second fog scenario, the MCS trained group did significantly better than the LCS trained group, but not better than the control group. The results showed that there were some improvements in hazard perception, but not in all scenarios. They also showed that for at least hazard perception training, a LCS offers too few opportunities. This experiment does not answer the question whether higher order skills can effectively be trained on a driver simulator or not. Much more research is required. However, it does indicate that one should be a bit cautious when estimating the potential of driver simulators for the acquisition of higher order skills.

Simulator training as an element in basic driver training

In the Netherlands, one of the largeest driver training schools, the ANWB driving course, has integrated simulator training and multi media training in their entire basic driver-training programme (Vlakveld, 2004). At first the driver simulator that can be considered as a MCS, but with a projected environment (with the aid of beamers) and a mock-up of a real car (but without a moving base) is used for an assessment of the learning capabilities of the applicant driver. This is a special test scenario. If these capabilities are rated as good, the applicant driver is offered a training programme of 10 days. During working days (8 days) the learner driver trains the whole day long. The training programme is structured in modules. The degree of complexity increases after each module, and for each module, training objectives are stated. Each module starts with a multi media training. The intention of this training is to show the learner driver (on film or animation) the skills that he has to acquire in the module, and to let him comprehend why the skills are executed that way. After this multi media session on a PC, the simulator training starts. A driver instructor is not directly involved during the simulator training, but an operator/instructor that operates more simulators simultaneously, might provide some additional instruction or feedback. As soon as the learner driver is behind the wheel of the simulator, a voice on tape tells him/her what to do. This 'virtual' driving instructor also automatically provides feedback during the training. The aim of the simulator training is to train the core of the skills in a reduced environment. What is not essential to the skill training is left out. Directly after the simulator training of about 20 minutes, the learner driver starts to drive with a driving instructor in real traffic (for about one hour). The aim is only to improve those skills of which the core was learned during the simulator lesson just before. After this driving lesson in real traffic, the learner driver has to observe another learner driver (from the rear seat) that is doing the same driving lesson he/she has just had. The intention is to learn from each other's mistakes. After this, the cycle (multi media training, simulator training, driver training in real traffic, observation of one's other driver training) starts all over again with the next module.

Unfortunately it is not known what the safety performance of drivers trained in this way is, compared to traditionally trained drivers. So far no evaluation study has been carried out. What is known, though, is that the passing rate for the driving test of this short but intensive training programme with the use of modern technology (multimedia training, simulator training) is slightly above average. It would be very interesting to know whether there is a difference in crash rate in the period just after having passed the driving test, between traditionally trained novice drivers and drivers that have attended this new training programme with the aid of driver simulators.

Conclusions

Now that quite advanced simulators have come available for training purposes, it is time to shift emphasis from the technical requirements to the pedagogical and didactical requirements. The development of the so-called courseware is still in its infancy. What is known, is that with well-developed training programmes for simulator training, the learning curve rises sooner than without the use of a simulator. What is not clear is whether there is some truth in the saying that what is learned quickly with the aid of a simulator will also be forgotten quickly. It also is questionable whether driver

simulators are good training devices for the acquisition of higher order skills, or that the driver simulator environment is too poor for the development of higher order skills. To answer these questions, much more research is required.

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